of old galls. These globular bodies vary in size but appear frequently of the same size in a given crown-gall cell. These bodies are conceded by Riker and Berge (63) to be of tannin, as pointed out by Milovidov (54). Milovidov studied the chondriosomes in the cell of *Pelargonium zonali* crown-gall and concluded that they do not differ from the normal chondriosomes as seen in the cotyledon of *Vicia faba*. The chondriosomes assume a typical form, stain typically and build starch. Crystals of calcium oxylate are also present. These substances are frequently found in crown-gall of the tomato, geranium, etc., as well as in the normal tissue.

Banfield (3), in his cytological studies on the cane-gall, came to a similar conclusion. The mass of gall tissue is initially composed of cells in every respect comparable with analogous cells of the meristematic region of the plants unaffected by cane-gall. Mucilage cells which constitute a conspicuous part of the histological structure of the cacti are absent in crown-galls experimentally produced in these plants (43–45).

In the non-parasitic tumors of the hybrid tobacco, Kostoff (33) reports cells with 21 chromosomes. This number is to be expected since the maternal element furnished 12 chromosomes and the male supplied 9 chromosomes. However, Kostoff (34) finds some cells in these tumors with 28, 30 and 42 chromosomes. The hybrid of *N. glauca* × *N. Langsdorfii* when crossed back with *N. Langsdorfii* produced fertile plants with tumors. The cells of these tumors show as many as 48 or more chromosomes. Whitaker (85) found no cytological abnormalities in the tumor cells of the hybrid (*N. glauca* × *N. Langsdorfii*). Chromosomes counted in over 40 cells showed no polyploidy. The mitoses were regular with little lagging or irregularity in chromosome behavior. Binucleate cells were not common. This apparent discrepancy may be attributed to variations in the tumor.

The differences pointed out above between crown-gall and cancer do not detract from the importance of Smith, Brown, Townsend, and McCulloch's discoveries. Crown-gall has at least one vital fundamental point in common with cancer, and that lies in the fact that crown-gall is a neoplastic disease consisting of a localized area of proliferating cells. While the proliferations are limited, i.e., because the gall ages, the botanist has the advantage in having an organism which, when injected into most plants, pro-

duces local cell growth and division. Crown-gall tissue represents essentially a fundamental tissue and, because of the simplicity of its host, is excellent material for the study of such problems as growth and reproduction and may thus throw light on the solution of the cancer problem.

Bibliography

1. Eichel, Otto. Ueber Zellverschmelzung mit qualitativ abnormer Chromosomenverteilung als Ursache der Geschwulstbildung. Vorträge u. Aufsätze über Entwick. der Org. **13**: 1–115. 1911.
2. Arnold, J. Beobachtungen über Kerntheilung in den Zellen der Geschwülste. Virch. Arch. **78**: 279–301. 1879.
3. Banfield, W. M. Studies in cellular pathology. I. Effects of cane-gall bacteria upon gall tissue cells of the black raspberry. Bot. Gaz. **97**: 193–239. 1935.
4. Bauer, K. H. Mutationstheorie der Geschwulstbildung. Leipzig, 1911.
5. Berridge, Emily M. Studies in bacteriosis. Ann. Appl. Biol. **17**: 289–283. 1930.
6. Blumenthal, F., and Hirschfeld, H. Untersuchungen über bösartige Geschwülste bei Pflanzen und ihren Erreger. Zeits. Krebsforsch. **16**: 51–58. 1917.
7. ————. Beiträge zur Kenntnis einiger durch *Bacterium tumefaciens* hervorgerufenen Pflanzengeschwülste. Zeits. Krebsforsch. **18**: 110–125. 1922.
8. Blumenthal, F., Auler, H., and Meyer, Paula. Ueber das Vorkommen neoplastischer Bakterien in menschlichen Krebsgeschwülsten. Zeits. Krebsforsch. **21**: 387–410. 1924.
9. Boveri, H. Zur Frage der Entstehung maligner Tumoren. pp. 64. 1914.
10. Brown, Nellie A., and Quirk, Agnes, J. Influence of bacteriophage on *Bacterium tumefaciens*, and some potential studies of filtrates. Jour. Agr. Res. **39**: 503–530. 1929.
11. Butler, E. J. Some aspects of the morbid anatomy of plants. Ann. Appl. Biol. **17**: 175–212. 1930.
12. Cavara, Fridiano. Intorno alla eziologia di alcune mallattie di piante coltivate. Staz. Sper. Agr. Ital. Modena **30**: 483. 1897.
13. Cornil, V. Sur le procédé de division indirecte des noyaux et des cellules épithéliales dans les tumeurs. Arch. de phys. norm. et path. III. **8**: 310–324. 1886.
14. Deton, W. Contribution à l'étude cytologique du cancer. La cellule. **27**: 27–52. 1911.
15. Ewing, James. Neoplastic diseases. 3rd ed., pp. 1127. 1928.
16. Farmer, J. B., Moore, J., and Walker, C. E. On the resemblance exhibited between cells of malignant growths in man and those of normal reproductive tissue. Proc. Roy. Soc. London **72**: 499–504. 1903.
17. Gaines, E. F., and Aase, Hannah C. A haploid wheat plant. Am. Jour. Bot. **13**: 373–385. 1926.
18. Galeotti, G. Ueber experimentelle Erzeugung von Unregelmässigkeiten des Karyokinetischen Processes. Beit. Path. Anat. Allg. Path. **14**: 288–316. 1893.
19. Goldschmidt, R., and Fischer, A. Chromosomenstudien an Karzinomzellen in vitro. Zeits. Krebsforsch. **30**: 281–285. 1929.
20. Handley, W. S. Cancer of the breast and its treatment. 2nd ed. 1922. N. Y.

21. Hedgcock, G. G. Field studies of the crown-gall of the grape. U. S. Dept. Agr. Bur. Pl. Ind. Bull. **183**: 1–40. 1910.
22. Heiberg, K. A., and Kemp, T. Ueber die Zahl der Chromosomen in Carcinomzellen beim Menschen. Virch. Arch. **273**: 693–700. 1929.
23. Hill, J. B. The migration of *Bacterium tumefaciens* in the tissue of tomato plants. Phytopath. **18**: 553–564. 1928.
24. Hill, J. B., Brittingham, W. H., Gibbons, Frances B., and Watts, Grace W. Further notes on *Bacterium tumefaciens* and its host relationship. Phytopath. **20**: 179–186. 1930.
25. Hirschfeld, H., and Klee-Rawidowicz, Eugenie. Cytologische Untersuchungen an Sarkomgewebe in-vitro-Kultur. Zeits. Krebsforsch. **30**: 406–422. 1929.
26. ————. Die Frage spezifischer morphologischer Merkmale der Tumorzelle, untersucht an Schnittpräparaten und an in vitro-Kulturen. Zeits. Krebsforsch. **32**: 139–145. 1930.
27. Jensen, C. O. Experimentelle Untersuchungen über Krebs bei Mäusen. Centralbl. Bakt. Abt. **1. 34**: 122–143. 1903.
28. ————. Von echten Geschwülsten bei Pflanzen. 2″ Rapport de la deuxième internat. conférence pour l'étude du cancer. 243–254. Paris. 1910.
29. ————. Undersøgelser vedrørende Nogle Svulstlignende Dannelser hos Planter Medd. fru Den. Kgl. Veter. Og. Land. Serum Lab. **54**: 91–143. 1918.
30. Kauffmann, F. Ueber Bakterienbefunde in Mäuse carcinomen. Zeits. Krebsforsch. **23**: 502–507. 1926.
31. ————. Zur Erzeugung von Pflanzengeschwülsten durch die aus Mäuse carcinomen isolierten Bakterien. Zeits. Krebsforsch. **24**: 260–262. 1926.
32. Klebs, E. Lehrbuch der allgemeinen Pathologie. 1889.
33. Kostoff, D. Tumor problem in the light of researches on plant tumors and galls and its relation to the problem of mutation. Protoplasma **20**: 440–456. 1933.
34. ————Heritable tumors in plants experimentally produced. Genetica **17**: 367–376. 1935.
35. Krompecher, E. Ueber die Mitose mehrkerniger Zellen und die Beziehung zwischen Mitose und Amitose. Virch. Arch. **142**: 447–473. 1895.
36. Levin, I., and Levine, M. Malignancy of the crown-gall and its analogy to animal cancer. Jour. Cancer Res. **5**: 243–260. 1920.
37. Levine, Michael. A comparative cytological study of the neoplasms of animals and plants. Jour. Cancer Res. **9**: 11–49. 1925.
38. ————. The so-called strands and secondary tumors in the crown-gall disease. Phytopath. **15**: 435–451. 1925.
39. ————. A comparison of the behavior of crown-gall and cancer transplants. Bull. Torrey Bot. Club **56**: 299–314. 1929.
40. ————. The chromosome number in crown-gall and cancer tissues. Phytopath. **19**: 97. 1929.
41. ————. The chromosome number in cancer tissue of man, of rodent, of bird and in crown-gall tissue of plants. Jour. Cancer Res. **14**: 400–425. 1930.
42. ————. Studies in the cytology of cancer. Am. Jour. Cancer **15**: 144–211. 788–834. 1411–1494. 1931.
43. ————. Crown-gall on Sahuaro (*Carnegia gigantea*). Bull. Torrey Bot. Club **60**: 9–16. 1933.
44. ————. A preliminary report on plants treated with the carcinogenic agents of animals. Bull. Torrey Bot. Club **61**: 103–118. 1934.
45. ————. Experimental production of crown-gall on *Opuntia*. Phytopath. **24**: 929–937. 1934.

46. ————. The response of plants to localized applications of various chemical agents. Bull. Torrey Bot. Club **63**: 177–199. 1936.
47. ————. Studies on *Bacterium tumefaciens* in culture media. Am. Jour. Bot. (in press). 1936.
48. Lewis, Margaret R., and Lockwood, Jane.. The tetraploid number of chromosomes in the malignant cell of the Walker Rat Sarcoma. No. 1. Bull. Johns Hopkins Hosp. **44**: 187–200. 1939.
49. Lewis, W. H. Normal and malignant cells. Science **81**: 545–553. 1935.
50. Loeb, Leo. On transplantation of tumors. Jour. Med. Res. N. S. **1**: 28–38. 1901.
51. ————. Further investigations in transplantation of tumors. Jour. Med. Res. N. S. **3**: 44–73. 1902.
52. Magrou, J. Recherches anatomiques et bactériologiques sur le cancer des plantes. Ann. Inst. Pasteur **41**: 785–801. 1927.
53. Martin, W. A. Zur Kenntnis der indirecten Kerntheilung. Virch. Arch. **86**: 57–67. 1881.
54. Milovidov, P. F. Zur Zytologie der Pflanzentumoren. Protoplasma **10**: 294–296. 1930.
55. Müller, V. Ueber celluläre Vorgänge in Geschwülsten. Virch. Arch. **130**: 512–528. 1892.
56. Nedjelsky, W. Ueber die amitotische Theilung in pathologischen Neubildungen, hauptsächlich Sarkomen und Carcinomen. Beitr. Path. Anat. Allg. Path. **27**: 431–483. 1900.
57. Němec, B. Ueber Pflanzentumoren. Arch. Exper. Zellforsch. **6**: 172–177. 1928.
58. Petri, L. I tumori batterici del Pino d'Aleppo. Ann. del R. Istituto Sup. For. Naz. **9**: 1–43. 1924.
59. Pinoy, E. A propos du cancer des plantes ou crown-gall. C. R. Acad. des Sci. **180**: 311–313. 1925.
60. Quirk, Agnes J., and Fawcett, Edna H. H-ion concentration vs. titratable acidity in culture mediums. Jour. Infect. Dis. **33**: 1–59. 1923.
61. Riker, A. J. Some morphological responses of the host tissue to the crown-gall organism. Jour. Agr. Res. **26**: 425–435. 1923.
62. ————. Cytological studies of crown-gall tissue. Amer. Jour. Bot. **14**: 25–37. 1927.
63. Riker, A. J., and Berge, T. O. Atypical and pathological multiplication of cells approached through studies on crown-gall. Amer. Jour. Cancer **25**: 310–356. 1935.
64. Robinson, W. Some features of crown-gall in plants in reference to comparisons with cancer. Proc. Roy. Soc. Med. **20**: 1507–1509. 1927.
65. Robinson, W., and Walkden, H. A critical study of crown-gall. Ann. Bot. **37**: 299–324. 1923.
66. Rosen, H. G. Morphological notes together with some ultrafiltration experiments on the crown-gall pathogene, *Bacterium tumefaciens*. Mycologia **18**: 193–205. 1926.
67. Ross, F. W. F. Observations on certain features exhibited by cells in their relation to cancer. Brit. Med. Jour. **2**: 1101–1102. 1905.
68. Rous, P. A transmissible avian neoplasm. (Sarcoma of the common fowl.) Jour. Exp. Med. **12**: 696–705. 1910.
69. ————. A sarcoma of the fowl transmissible by an agent separable from the tumor cells. Jour. Exp. Med. **13**: 397–411. 1911.
70. Smith, E. F. Studies on the crown-gall of plants. Its relation to human cancer. Jour. Cancer Res. **1**: 231–258. 1916.
71. ————. Further evidence as to the relation between crown-gall and cancer. Proc. Nat. Acad. Sci. Balt. **2**: 444–448. 1916.

72. ————. Further evidence that crown-gall of plant is cancer. Science **43**: 871–889. 1916.
73. ————. Crown-gall and cancer. Jour. Amer. Med. Ass. **67**: 1318. 1916.
74. ————. Mechanism of tumor growth in crown-gall. Jour. Agr. Res. **8**: 165–186. 1917.
75. ————. Twenty century advances in cancer research. Jour. Radiology **4**: 295–317. 1923.
76. Smith, E. F., Brown, Nellie A., and Townsend, C. O. Crown-gall of plants; its cause and remedy. U. S. Dept. Agr. Bull. 213: 1–215. 1911.
77. Smith, E. F., Brown, Nellie A., and McCulloch, Lucia. The structure and development of crown-gall. U. S. Dept. Agr. Bull. 255: 1–60. 1912.
78. Smith, E. F., and Townsend, C. O. A plant tumor of bacterial origin. Science **25**: 671–673. 1907.
79. Stein, Emmy. Weitere Analyse der Gruppe A von den durch Radiumbestrahlung veränderten Erbanlagen bei *Antirrhinum*. Kern- und Zellveränderung in der krebsigen Gewebentartung. Zeits. Indukt. Abst. Vererb. **69**: 303–326. 1935.
80. Stroebe, H. Ueber Vorkommen und Bedeutung der asymmetrischen Karyokinese nebst Bemerkungen über die Schlummerzellen in der verletzten Cornea. Beitr. Path. Anat. Allg. Path. **14**: 154–173. 1893.
81. Toumey, J. W. An inquiry into the cause and nature of crown-gall. Bull. Arizona Agr. Exp. Sta. **33**: 7–64. 1900.
82. Trambusti, A. Ueber den Bau und die Theilung der Sarkomzellen. Beitr. Path. Anat. Allg. Path. **22**: 88–104. 1897.
83. Virchow, R. Die endogene Zellenbildung beim Krebs. Virch. Arch. **3**: 197–227. 1851.
84. Von Hansemann, D. Ueber asymmetrische Zellteilung in Epithelkrebsen und deren biologische Bedeutung. Virch. Arch. **119**: 299–326. 1890.
85. Whitaker, T. W. The occurrence of tumors on certain *Nicotiana* hybrids. Jour. Arn. Arb. **15**: 144–153. 1934.
86. Whitman, R. C. Somatic mutations as a factor in the production of cancer; a critical review of von Hansemann's theory of anaplasia in the light of modern knowledge of genetics. Jour. Cancer Res. **4**: 181–202. 1919.
87. Winge, O. Zytologische Untersuchungen über die Natur maligner Tumoren. I. "Crown-gall" der Zuckerrübe. Zeits. Zellforsch. Mikr. Anat. **6**: 397–423. 1927.
88. Winiwater, H. v., and Oguma, K. Nouvelles recherches sur la spermatogenèse humaine. Arch. Biol. **36**: 99–106. 1926.

THE OEDOGONIALES*

LEWIS HANFORD TIFFANY

INTRODUCTION

In the whole range of Chlorophycean genera there is perhaps no other order as distinctly separate and as unlikely to be mistaken for other algae as the Oedogoniales. This is especially true when reproductive structures are present. Even an amateur quickly learns to recognize without fail an *Oedogonium,* a *Bulbochaete,* or an *Oedocladium* by means of vegetative characteristics alone. The most outstanding features of the group, merely to mention them for the present, are the curiously rigid vegetative cells often with apical caps, the reticulate chloroplasts, the holdfast cells, the large zoospores with a crown of cilia at the anterior end, and, of course, the prominent oogonia and antheridia.

The single family, Oedogoniaceae, was established by De Bary (4) in 1854 and now includes three genera: *Bulbochaete* C. A. Agardh (2), *Oedogonium* Link (12), and *Oedocladium* Stahl (20). The systematics of the group, brought up to date in 1930 by Tiffany (24), were first put into an orderly fashion in a splendid monograph by Hirn (9). Unusual interest in the Oedogoniales, both in this country and abroad, has been manifest during the last few decades. Numerous papers have appeared describing new species, extending the geographic range and discussing various phases of reproductive and physiological activities. This report will endeavor to correlate some of these more recent investigations with our previous knowledge of the group.

The following summary table gives the present numerical status of the three genera. Incompletely described or doubtful species are not included.

Genus	Species	Varieties	Forms
Oedogonium	296	49	18
Bulbochaete	66	8	5
Oedocladium	6	0	0

* Papers from the Department of Botany, The Ohio State University, No. 370.

DISTRIBUTION AND PERIODICITY

That many species of *Oedogonium* and *Bulbochaete* are widely distributed in fresh waters throughout the world is becoming increasingly evident with every algological survey of new regions. In fact, "geographical distribution" of many of these species means little more than the location of phycologists, past and present, who have interested themselves in the algae about them. Absence of precise structural limitations sometimes makes species differentiation hazardous, but these difficulties are just as likely to be met in collections from a single location as from widely separated habitats. In other words, speaking generally for the temperate and tropical realms, one is driven to the conclusion that the distribution of the species is dependent upon something much more basic than physical divisions or continental areas.

If we are able to put together the scattered data resulting from analyses of local habitats over a rather wide area, we may secure some picture of the ecological and physiological situation underlying the distribution of the Oedogoniales. Bukatsch (3) finds the optimum temperature for photosynthesis in certain species of *Oedogonium* to lie between 25° and 30° C. This is of course subject to variation due to the depth of submergence of the plant and to the difference in available solar radiation. Many species of both *Oedogonium* and *Bulbochaete* in North America, however, grow luxuriantly in waters of a temperature as low as 18–20° C. A few species are able to maintain themselves at temperatures slightly above freezing and may survive after being frozen in ice for several weeks. In very shallow quiet inlets on the south shore of Lake Erie *Oe. landsboroughi* (Hass.) Wittr. and *B. varians* Wittr., as well as a few other of the larger species, are apparently uninjured after a few hours each day in light of high intensity and water up to 50° C. In midsummer shallow water may become deficient in CO_2, and the algae may die of starvation rather than because of any harmful effects of high temperatures and intense light.

Sexual reproduction is more likely to occur in *Oedogonium* and *Bulbochaete* if the water is slightly alkaline: Mainx (14) found the optimum to be pH 7.2 to 8.2. *B. varians* var. *subsimplex* (Wittr.) Hirn regularly fruits in Ohio at a pH as high as 8.8. Ackley (1) records 17 species of fruiting *Bulbochaete* and

Oedogonium as occurring in acid bogs of Michigan with pH varying from 3.4 to 6.8. It is thus seen that rather large differences in hydrogen-ion concentration are tolerated at least by some species.

Phosphates and nitrates, and perhaps the salts of calcium and magnesium, are important in the vegetative growth of *Oedogonium*. Prairie ponds and pools of Illinois and cypress swamps of Florida are much richer in numbers of both individuals and species than the cattail marshes along Lake Erie or the waters of the Ohio shales. Taft (22) finds that the Oedogoniales flourish in Oklahoma in both shale and sandstone areas, and McInteer (13) associates best growth of these filamentous algae with the fertile Bluegrass region of Kentucky.

Oe. reinschii Roy, long known vegetatively from northern latitudes of the United States and Europe, apparently maintains itself in such sections wholly asexually. Oogonial and antheridial filaments have been collected solely from southern Florida and only in the month of May.

Although an attempt to correlate abundance of *Oedogonium* and *Bulbochaete* with ecological associations and formations of land plants is somewhat hazardous, the following facts are significant, provided it is kept in mind that purely local data considered alone may materially alter any general conclusion. In America the waters most productive of the Oedogoniales, excluding *Oedocladium,* lie in the tall-grass prairies, the eastern deciduous forest, and that part of the southeastern conifer forest in the Mississippi Valley. The subtropical and tropical forest areas and grasslands of Florida, Brazil and similar regions are almost equally rich in species. The coastal plain perhaps ranks fourth. Far below these regions in productiveness are the short-grass plains, the semi-deserts, the western conifer forests, and, with few exceptions, the northeastern evergreen forest.

In general, then, the criteria for the growth and maintenance of many of the Oedogoniales appear to be quite simple: relatively quiet water, including ponds and pools, shallow parts of lakes, oxbows, and sluggish streams provided with the necessary mineral salts; absence of shade; mud rather than sand or easily movable bottom; a pH on the alkaline side; and a growing season of sufficient length to allow for completion of vegetative and repro-

ductive cycles. The nearly world-wide distribution of some species may be accounted for by the almost universal presence of these ecological conditions in bodies of fresh water. The fact that several species of *Oedogonium* are found in practically every country on the globe indicates that the genus is geologically old enough to allow for such distribution by natural means (e.g., birds, air currents, etc.) or that identical evolution occurred in similar habitats in many quarters.

The species of *Oedocladium,* on the other hand, perhaps because of our limited knowledge of the genus, seem to contradict the generality of distribution just enunciated. There are now known six species of *Oedocladium* (Tiffany, 25) : one each from Germany, Massachusetts, Virginia, New Jersey, Florida, and Puerto Rico. It is interesting to note, in passing, that the first species on which the genus was established was found in Germany in 1891 and has not been seen since, and that the other five species occur in the eastern seaboard of the United States. Only one of the species of *Oedocladium* is aquatic, the remainder being terrestrial and growing on wet mud or sandy loam.

Hirn (9) reports three species of *Oedogonium* and one of *Bulbochaete* from brackish waters of Europe. Fritsch (6) collected vegetative filaments of the former genus as a part of the red and yellow snow of the Orkneys. Both genera are represented vegetatively at considerable elevations in alpine regions. The ratio of species found in such habitats to the total number in the family is about on the order of 1 : 50.

The relative importance of habitats for the growth of *Oedogonium* and *Bulbochaete* has been investigated by Tiffany and Transeau (26) for the north central States of America. Out of a total of about 1200 records of collections over a period of some twenty years they find: 54% of the species in permanent ponds, 23% in lakes, 15% in temporary ponds, 6% in streams, and 2% in stream oxbows. These percentages are based upon exact determination which necessitates the presence of fruiting material; otherwise, identification of species is not possible. The still-too-numerous pseudoscientists to whom holdfast cells in both *Oedogonium* and *Bulbochaete* must be adaptations for a life in running water will find it a bit difficult to account for the scarcity of these plants in streams.

Species of *Oedogonium* and *Bulbochaete* in many places fruit for the most part at rather definite seasons of the year. Usually the smaller the alga, the shorter the vegetative phase and the earlier the time of sexual reproduction; conversely, the larger the alga, the longer the vegetative period and the later the production of sperms and eggs. There are, however, some notable exceptions. In the north central United States maximal sexual reproduction is reached in May–July with a second lesser maximum in October. The latter is quite likely the development of a second generation.

In tropical and subtropical countries such definite periodicities do not obtain. Collections from Florida, some parts of the Coastal Plain, Puerto Rico, and Brazil appear to indicate that maximum fruiting follows the rainy seasons. This coincides with Transeau's (27) general deduction from data gathered in southern Illinois that maximal fruiting of algae occurs not in low-water periods when the ponds are drying up but rather in high-water periods. The presence of 30 species of *Oedogonium* and *Bulbochaete* in a single collection from a cypress swamp pool near Arcadia, Florida, in 1931 may be accounted for by the simultaneous germination of oospores of varying lengths of dormancy, as will be noted below.

A clear picture of periodicity in *Bulbochaete* and *Oedogonium* is made difficult by two other factors, at present practically unstudied: (a) the length of the dormant period in the oospore and (b) the persistence of vegetative material perennially or through zoospore production only. It is definitely known that while most oospores in the north central United States are dormant for the winter following their formation, some germinate in the same autumn and a few others lie in the mud at the bottom of ponds for several years. It seems quite probable that extreme desiccation due to the drying up of the water may be endured for considerable lengths of time. There is evidence for the reappearance of *Oedogonium* "waves" every three, four, five or even eight years. Mainx (14) finds that a rest period of a year is necessary before oospores of *Oe. gracilius* (Wittr.) Tiffany will germinate.

A few species, like *Oe. grande* Ktz., have been collected in fruit from ponds of Illinois every month in the year, although the records for December and January are few. In cool streams, in alpine regions, and in subarctic waters *Oedogonium* may survive vegetatively from year to year. Many species exist perennially in

a vegetative state although fruiting at rather definite periods. Such ubiquity of spore production as illustrated by *Oe. grande* is rare among the filamentous algae.

Some interesting daily periodicities in the production of sperms and subsequent fertilization of the egg have been observed by Spessard (19) (*cf. post*). Zoospores apparently may be produced from vegetative cells nearly any time up to the initiation of sexual reproduction. Changes of temperature of medium, transfer from distilled water to a nutrient solution or the reverse, exposure to light after storage in the dark are some of the methods in use in the production of zoospores at will. Gussewa (8) maintains that zoospore production is inhibited by too low concentrations of ferric salts and conditioned by the presence of a certain amount of free CO_2 in the water. In nature zoospores are not formed in running water so abundantly as in quiet water.

CELL STRUCTURE AND DIVISION

The vegetative filaments of *Oedogonium* are unbranched, attached when young and in many cases for some time thereafter, and composed in most species of cylindrical cells. A number of species, however, exhibit variations—usually constant, sometimes not—from the cylindrical shape of cell, such as capitellate, undulate, nodulose, ellipsoid, or even apparently sub-hexagonal. In *Bulbochaete* the filaments are unilaterally branched and made up of cells usually broader at the upper end and bearing long, basally bulbous setae. The species of *Oedocladium* are also branched, but there is a differentiation into erect and creeping branches with chloroplasts and into rhizoidal branches of long slender cells devoid of chloroplasts. In the single aquatic species of *Oedocladium*, however, both kinds of branches are green. The cells of *Oedocladium* uniformly lack setae.

Attachment to various substrata, including macrophytes, algae, and even other species of the Oedogoniaceae, is made by a holdfast cell in both *Bulbochaete* and *Oedogonium*. *Oedocladium*, on the other hand, is without a cell of attachment. Even when free-floating, however, there is no difficulty in ascertaining the apical and basal ends of the filaments in all three genera: definite polarity is maintained throughout the life of the plant.

The resting nucleus of the vegetative cell is large, usually circular and flattened in appearance, and generally lies just within the chloroplast midway between the ends of the cell. It has a distinct nuclear membrane, an abundance of chromatin at the nodes of the network just within the membrane, and one or more nucleoli (15). The chloroplast is elaborately reticulate with the strands of the reticulum either broad or narrow and usually parallel to the long axis of the cell. The numerous pyrenoids occur at the intersections of the reticulum and are surrounded by sheaths of starch plates. The accumulation of plates of starch elsewhere in the reticulum may entirely obscure the usual appearance of the chloroplast.

The cell walls of the Oedogoniales are rigid and usually devoid of conspicuous mucilage, except in some species of *Bulbochaete*. According to van Wisselingh (29), the cell wall of *Oedogonium* consists of an inner cellulose membrane with a peripheral investvent of perhaps amyloid. Wurdack (30) finds the cellulose inner layer to be bound externally by a zone of pectose which is covered in turn by chitin. Recent unpublished work seems to confirm both the cellulose and the pectic compounds, but throws some doubt upon the certain identity of the chitin. The outermost layer is undoubtedly not cellulose, but its exact chemical nature will have to await a more refined microchemical test than now in use. The composition of the cell walls of both *Oedocladium* and *Bulbochaete* is apparently similar to that of *Oedogonium*. The holdfast cells are generally devoid of this peripheral, chitin-like substance (23).

In the past three quarters of a century cell division in *Oedogonium* has been investigated by various workers. Perhaps the best accounts in more recent years are those of van Wisselingh (29), Tuttle (28), Kretschmer (11) and Ohashi (15). The nucleus moves distally from its mid-position between the end septa and comes to rest at a position about one-third the distance from the upper end of the cell. After enlarging and changing shape somewhat, it divides mitotically. At prophase most investigators report the appearance of a ring, which Steinecke (21) believes to be hemicellulose, completely enveloping the inner face of the lateral wall just below the upper extremity of the cell.

Whitford*, who has recently made microchemical analyses of all three genera, feels that the ring "is not an isolated mass of wall material formed at that particular spot, but is merely an inwardly bulging thickened portion of a complete new layer laid down inside the old wall and entirely inclosing the protoplast. Upon the stretching of the ring the distal cell (to be) is inclosed by a single wall layer, except under the cap, composed of the distended ring; the forthcoming proximal cell, however, is inclosed by two or more wall layers, except at the distal end". The protoplast may divide before the ring stretches, but the transverse wall is found only after the daughter cells cease elongation. The septum soon connects with the lateral walls, and separation into two cells is complete. After a number of divisions the distal cell is surmounted by a number of shallow telescoping (apical) caps, each representing a division. In the large species of *Oedogonium* and probably in most species of *Bulbochaete,* the lower part or sheath cell may also divide and after a number of divisions is inclosed, except at the top, by a corresponding number of layers. Whitford has found cellulose in the ring long before any evidence of stretching appears, but all tests for hemicellulose are negative.

Cell division is intercalary in *Oedogonium,* resulting in cells with varying numbers of apical caps; it takes place usually terminally in *Oedocladium,* and so the end cell is generally the only one with the caps; in many species of *Bulbochaete* it is strictly basal and thus rarely more than one apical cap to a cell. In *Oedocladium* the caps may be pushed aside or disappear entirely after some growth of the plant.

Early cytological investigation of cell division in *Oedogonium* did not, of course, include a study of chromosomes. More recently, however, van Wisselingh (29) reports 19 chromosomes in *Oe. cyathigerum* Wittr., Ohashi (15) counts 13 in *Oe. grande* Ktz., and Kretschmer (11) finds 15 in *Oe. pachyandrium* Wittr. It is of interest to record this uneven number of chromosomes and to speculate upon the genetic behavior at reduction division. Ohashi (15) notes in cell division in *Oe. grande* that the chromosomes at metaphase show great diversity in form and shape. The forms usually assumed are short rods, long rods, and loops.

* Communication from Prof. L. A. Whitford, North Carolina State College, Raleigh.

Division of the cells of *Oedogonium* takes place rapidly if external conditions are favorable. Slight desiccation of young filaments followed by immersion seems to accelerate cell division. Freund (reported by Fritsch, 7) maintains that a deficiency of requisite salts tends to stop division, the cells lengthening and becoming filled with reserves. Heavy incrustation of the filaments with calcium carbonate slows the process of cell division but does not prevent its occurrence. The recently formed cells, in such cases, stand out prominently because of the entire absence of the peripheral deposit.

ZOOSPORE FORMATION AND GERMINATION

Multiciliate zoospores arise singly from vegetative cells of all three genera. The formation and liberation of the swarmers can readily be followed if plants, previous to sexual reproduction, are brought into a warm room and observed from time to time under a microscope, (*cf. ante*). The first noticeable change in the vegetative cell about to form a zoospore is a slight contraction of the protoplast and the appearance of a colorless area between the nucleus and the wall. Around the margin of the hyaline area appears a ring of blepharoplast granules, each perhaps giving rise to a flagellum (Smith, 1934). Kretschmer (11) describes two rings of basal granules forming flagella in zoospores, but Gussewa (8) reports only a single ring-shaped blephoraplast in *Oe. capillare* (L.) Ktz.

A circular rent appears near the upper extremity of the cell. Steinecke (21) reports the change of cellulose into amyloid at the place of rupture, just previous to the appearance of the aperture. The zoospore slowly emerges in an amoeboid fashion inclosed by a pectic sheath, the liberation requiring but a few minutes. Steinecke (21) assumes that rupture of the wall and subsequent emergence of the zoospores are due to the swelling of gelatinous substances secreted at both ends of the cell by the protoplast. The gelatinous vesicle at first enlarges, then rapidly disappears, after emergence of the zoospore. The spore moves sluggishly while the gelatinous material is dissolving, but becomes very active upon the formation of the crown of flagella around the clear anterior end, from granules as noted above.

The zoospores are spherical or ovoid or pyriform and quite green in color except for the colorless beak around the base of which the flagella are attached. Mainx (14) reports the uniform presence of an eyespot. Zoospores are usually active for an hour or more before coming to rest. Fritsch (5) observed the formation of further zoospores from the one-celled stage. Usually, however, the quiescent zoospore in *Oedogonium* forms attachment by the development of a holdfast cell, the complexity of which apparently depends upon the nature of the substratum. Subsequent division of the sporeling forms the filament characteristic of the genus to which it belongs.

In *Bulbochaete* the first division of the zoospore is of the simple type without formation of a ring. The upper part of the cell is separated from the lower by a circular rent, but no new membrane develops between the two parts. As the new wall grows upward, the separated part is pushed to one side as a lid. The upper new cell grows out into a long tubular bristle with a swollen bulbous base. Subsequent divisions occur with the regular ring formation, and each new cell is intercalated between the basal cell and the next one above. The upper cell of each filament is, therefore, the oldest one. A lateral protusion of each cell at its apex is cut off, developing into a hair. It is thus seen that the terminal cell bears two hairs, the other cells one each. Nearly every cell of *Bulbochaete* has two apical faces, one bearing a hair (or a cell of a side branch), the other the next upper cell of the main axis. Every cell of the principal axis of the filament, except the basal one, may cut off by an oblique division a lateral cell which becomes the basal cell for a side branch. By repeated divisions, as noted above, this secondary basal cell forms the branch.

The first cell formed in *Oedocladium* upon germination of the zoospore may develop variously: into a green filament without early branching or with a rhizodial cell as a branch or with a green cell as a branch. No holdfast cells are formed. The formation of a branch in *Oedocladium* occurs by development of a circular rent in the upper extremity of a vegetative cell, forming an upper short "lid" and a lower cylindrical piece. Through this rent the protoplasm of the forthcoming daughter branch cell with its initially thin wall protrudes. A new wall separating the branch cell from the cell of the main filament is then developed. This

wall is attached to the juncture of the upper extremity of the cylindrical piece of the primary cell and the lower end of the branch cell, on the one hand, and to the original transverse wall of the primary cell, on the other.

Asexual reproduction other than through zoospore formation is effected also through formation of akinetes, although they are relatively uncommon. In *Oedogonium* the akinetes occur in the ordinary filaments either singly or in chains of 10 to 40 in number (18). In terrestrial species of *Oedocladium* they develop similarly in the rhizoids and are frequently rich in reserve foods and nearly always red in color. Akinetes germinate directly into new plants. When filaments of *Oedogonium* are heavily incrusted with lime or infested with fungal parasites, single aplanospore-like structures appear as spheroid or ovoid bodies in the middle of the vegetative cell. The entire protoplast appears to take part in their formation. The fate of such a "resting spore" is unknown.

SEXUAL REPRODUCTION

Sexual reproduction is of an advanced oogamous type in all the Oedogoniales, and certain phases of it are so unique as to have developed a very specialized terminology. External conditions must be suitable (*cf. ante*), and chief among these is a hydrogen-ion concentration on the alkaline side, which Mainx (14) sets at a pH of 7.4 to 8.2 for most filaments. It should be kept in mind, however, that a certain development or maturation within the plant, the acquiring of a so-called sexual tonus, is probably more important than any special complex of environmental factors. As a matter of fact, when this "state" has been reached, it is practically impossible to prevent sexual reproduction in many species of *Oedogonium* without destroying the filaments. It is interesting, in passing, to recall that ponds of prairie areas produce fruiting material much more abundantly than those of many other regions generally poor in necessary mineral salts.

Perhaps the most unusual characteristic of the reproductive structures of the Oedogoniales is the dwarf male, a short filament epiphytic on or near the oogonium and usually composed of a holdfast cell and one or more antheridia. Species with such dwarf males are "nannandrous" and always dioecious. If there are no dwarf males, the plant is "macrandrous" and as such may be either

monoecious or dioecious. The dwarf males arise from the germination of androspores, which are zoospore- or gamete-like swarmers produced in short cells known as androsporangia. If the androsporangia are formed on the same filament as the oogonia, the species is "gynandrosporous"; if on separate threads, the plant is "idioandrosporous." It should be pointed out that a very few macrandrous species of *Oedogonium* are either dioecious or monoecious and that some of the nannandrous forms of both *Oedogonium* and *Bulbochaete* are either gynandrosporous or idioandrosporous.

Apparently any vegetative cell, except the basal one in *Bulbochaete* and *Oedogonium* and the rhizoidal cell in *Oedocladium,* may become an oogonium-mother cell. Just why relatively few cells of any given filament are differentiated into oogonia is not known, but it is perhaps associated with abundance of food reserves. In *Oedogonium* and *Oedocladium* a transverse division of a vegetative cell results in two segments. The upper one enlarges and becomes the oogonium; the lower segment or sheath-cell forms the supporting or suffultory cell. In *Oedogonium* the suffultory cell may undergo further segmentation, resulting in seriate oogonia. In some species the swollen nature of the suffultory cell is of diagnostic value. Ohashi (15) reports the absence of a supporting cell in *Oe. americanum* Transeau.

In *Bulbochaete* the oogonia are not seriate. An oogonium arises by a double division of a vegetative cell and so has two suffultory cells that may be of equal or unequal length. The relative lengths of the two supporting cells are fairly constant features for a given species in the genus. If the two divisions of the oogonium-mother cell are at right angles to the long axis of the vegetative cells, the oogonium is "erect"; if one division is oblique, giving one suffultory cell a five-sided, or five-angled, appearance (viewed in optical section), the oogonium is "patent." In members of the genus with globose (or nearly so) oogonia, the upper and not the lower suffultory cell is five-angled, while in those with more ellipsoid oogonia the reverse is true. In the latter case the upper cell is quite small, or may not be visible. A patent oogonium is always formed by a division of the basal cell of a side branch, with which may be associated a bulbous hair, an androsporangium, an antheridium, or rarely a vegetative cell. An erect oogonium on the other hand forms from a division of some vegetative cell other than

the basal one. In the globose forms of the genus, patent oogonia are common while erect oogonia occur only in a few species. Among the ellipsoid forms both kinds are found.

The oogonium is of various shapes and with few exceptions has a diameter greater than that of the vegetative cells. It contains a single egg having a centrally placed nucleus in early stages of development (15). As the oogonium nears maturity, a small pore forms in the wall by the appearance of soluble pectic material at the tip of a papillary projection; in some species a similarly formed transverse slit may separate the lower from the upper part of the oogonium, resulting in a lid. The position of the pore in the poriferous species and of the slit for the operculate species is quite constant for a given species and has real diagnostic value.

The antheridia of macrandrous species are flat, discoid cells developed by repeated transverse divisions of a vegetative cell. The first division is always near the upper part of the cell, and subsequent partition of the lower segment of the mother cell may result in a series of 2 to 45 antheridia in a single filament. The protoplast of the antheridia may upon maturity form a single sperm, but it usually forms two sperms, either by a transverse or a vertical division. Liberation of the sperm is practically identical with that of the zoospore described above.

Antheridia of nannandrous species are produced on dwarf males that result from germination of androspores. Flat discoid androsporangia, formed from vegetative cells in the same way as the antheridia of macrandrous species, produce each a single swarmer or androspore. Upon escape from the androsporangium in the manner of a sperm or zoospore, the androspore comes to rest, after about an hour, usually on the oogonium or suffultory cell. In some species of *Oedogonium* and rarely in *Bulbochaete* the androspore may become affixed to a vegetative cell considerably remote from the oogonium. Such cells are assumed to be potential oogonium-mother cells that never became morphologically differentiated. In some collections of *Oedogonium* from Florida the writer has observed a few germinated androspores on unrelated filaments of the same genus or even on cells of *Cladophora.* At any rate the androspore grows into a sporeling with a holdfast cell and one or more antheridia, the latter forming as in the macrandrous plants. In some cases the dwarf male may have a few vegetative cells

between the holdfast cell and the antheridia. Some nannandrous species, especially the smaller ones, have one-celled dwarf males, and in such cases the upper part of the holdfast cell acts as an antheridium. Each antheridium normally contains two sperms, formed by a horizontal division of the protoplast.

The dwarf males of the Oedogoniales have been the subject of much speculation by phycologists. Pascher (16) regards the species possessing dwarf males as the more primitive since three kinds of swarmers are really present: zoospores, androspores, and sperms. The intermediate androspores are zoospores that are incapable of complete vegetative development and so give rise to dwarf filaments producing male cells. Further evolution of the protoplast of the androsporangium made it possible to produce sperms directly. The macrandrous forms are thus to be regarded as the more highly specialized.

Most investigators incline to the view, however, that the macrandrous group gave rise to the nannandrous. It is common observation that many of the ordinary male filaments are frequently smaller than the female and that quite young dioecious plants may form antheridia. These two facts are used as evidence to support the claim that the dwarf males are but reduced antheridial filaments of dioecious macrandrous types. Schaffner (17) regards androspores as modified sperms that have retained some degree of sexuality; that is, they react sufficiently to the oogonium or suffultory cell to lodge there, but not sufficiently to fuse with the egg. An androspore may thus be regarded as a sperm that develops parthenogenetically into a dwarf male. The presence of dwarf males on cells of *Cladophora,* mentioned above, may be accounted for by the proximity of oogonial filaments of *Oedogonium* at the time of the attachment and germination of the androspores.

Fertilization in all three genera occurs after the sperm swims through the opening in the oogonial wall. According to Spessard (19), the sex organs of *Oe. kurzii* Zeller are mature in about 48 hours after their differentiation from ordinary cells, antheridia are formed about a day after the oogonia—thus seemingly insuring cross fertilization—and maximal sex organ production occurs about every fifteen days. The sperms of this same species are liberated throughout the period of sexual activity, but maximal emergence occurs between midnight and four A. M. A second

lesser wave may be seen from noon to four P. M. Fertilization in *Oe. kurzii* may take place within ten minutes after the discharge of the sperm. Passage of the male gamete through the conduit may require from a few seconds to four or five minutes, but the actual entry into the egg consumes only a half minute. The cilia of the sperm have long been regarded as relatively short structures, but Spessard reports those for *Oe. kurzii* to be much longer than the body of the gamete itself.

The sperm makes contact with the egg anterior end first in *Oe. kurzii,* which is contrary to the usual interpretation placed on the figure of Klebahn (10) for *Oe. boscii* (LeCl.) Wittr. The contents of the female gamete are pushed inward by the entering sperm and the membrane immediately "heals" over after the posterior end of the male cell has completed passage. Fusion of the two nuclei occurs without delay. The male nucleus is always the smaller and devoid of a nucleolus (15). The female nucleus before fertilization moves from its central position in the egg near the oogonial aperture. The fusion nucleus is somewhat globular in shape. Differentiation of the spore wall soon becomes noticeable, and the mature oospore has three (sometimes two or even four) membranes: the inner one nearly always smooth, the middle one often highly ornamented, and the outer layer sometimes ornamented, more often not. The ornamentations are quite constant in the oospore of a given species, and thus furnish excellent criteria for accurate identification.

The oospore of *Oe. gracilius* undergoes a rest period of a year before germination. The species becoming sexually mature in autumn, however, have grown from oospores whose dormant period was six months or even less. There is little doubt, on the other hand, that dormancy (*cf. ante*) may be a matter of several years in some species of *Oedogonium.* Mainx (14) observes that after the elapse of a year, 100 per cent germination of oospores may be obtained after 24 to 48 hours in ice-water and then transference to a nutrient solution. Normally, the oospore of *Oe. gracilius* produces 4 zoospores, two of which give rise to antheridial filaments and two to oogonial filaments. This may be the case in all dioecious plants of *Oedogonium.* Although unable to ascertain either the haploid or diploid number of chromosomes, Gussewa (8) gives evidence for reduction division at the time of germination of the

oospore in *Oe. capillare*. This confirms what has long been assumed, and it is quite probable that all Oedogoniales are haploid. Not all of the four nuclei formed in germination of the oospore may produce zoospores, and this accounts perhaps for the occasional observation of only one or two or three swarmers from a single zygote. It has been suspected that the oospore of some species may under certain conditions germinate directly into a filament, but this as yet lacks confirmation.

Another observation by Mainx (14) is unusual. In some cases a zygote gives rise to a single, large, presumably diploid zoospore which grows into a filament twice the normal size and always female. The oogonia of such plants are, however, flatter in appearance, and their formation in series suggests antheridia. Mainx regards the factor for femaleness as dominant, but the recessive factor for maleness may show itself in the "antheridial" features of the oogonia. The eggs produced from such oogonia may be fertilized by normal haploid sperms, but further development of the presumably triploid oospore is not known.

Parthenospores have been seen in *Oedogonium* from time to time, and Gussewa (8) records their formation in *Oe. capillare* from the entire contents of the vegetative cells. They develop thick walls and occupy all the space within the cells except the corners. They look much like oospores, but neither a pore nor a slit is in evidence in the mother-cell wall. Gussewa's statement that the parthenospores germinate immediately into new filaments is difficult to accept in view of the presence of such a thick investment.

Literature Cited

1. Ackley, A. B. A survey of the algae of Michigan. Abst. Doctors' Diss., Ohio State Univ. 1–13. 1930.
2. Agardh, C. A. Synopsis algarum Scandinaviae, adjecta dispositione universali algarum. pp. i–xl; 1–135. 1817. Lund.
3. Bukatsch, F. Beiträge zur Kenntnis der Kohlensäure-assimilation durch Süswasseralgen. Jahr. Wiss. Bot. **81**: 419–447. 1935.
4. De Bary, O. Ueber die Algengattung en *Oedogonium* und *Bulbochaete*. Abhandl. Senckbergischen Ges. **1**: 29–104. 1854.
5. Fritsch, F. E. The germination of zoospores in *Oedogonium*. Ann. Bot. **16**: 412–417; 467–485. 1902.
6. ————. Freshwater algae of the South Orkneys. Rep. Sci. Results Scot. Antarctic Exp. **3**: 95–134. 1912.
7. ————. The structure and reproduction of the algae. 791 pp. 1935.
8. Gussewa, K. Über die geschlechtliche und ungeschlechtliche Fortpflanzung von *Oedogonium capillare* Ktz. in Lichte der sie bestimmenden Verhältnisse. Planta **12**: 293–326. 1930.

9. Hirn, Karl E. Monographie und Iconographie der Oedogoniaceen. Acta Soc. Sci. Fennicae **27**: 1–394. 1900.
10. Klebahn, H. Studien über Zygoten. II. Befruchtung von *Oedogonium boscii*. Pring. Jahrb. Wiss. Bot. **24**: 235–267. 1892.
11. Kretschmer, H. Beiträge zur Cytologie von *Oedogonium*. Arch. Protistenk. **71**: 101–138. 1930.
12. Link, H. F. Epistola de Algis aquaticis in genera disponendis. In C. G. H. Nees von Esenback's Horae physicae berolinenses. pp. 1–8. 1820.
13. McInteer, B. B. A survey of the algae of Kentucky. Abst. Doctors' Diss. Ohio State Univ. **10**: 216–222. 1933.
14. Mainx, F. Physiologische und genetische Untersuchungen an *Oedogonium*. I. Zeits. Bot. **24**: 481–527. 1931.
15. Ohashi, H. Cytological study of *Oedogonium*. Bot. Gaz. **90**: 177–197. 1930.
16. Pascher, A. Über die Zwergmännchen der Oedogoniaceen. Hedwigia **46**: 265–278. 1906.
17. Schaffner, J. H. Extraordinary sexual phenomena in plants. Bull. Torrey Bot. Club **54**: 619–629. 1927.
18. Smith, G. M. Fresh-water algae of the United States. 716 pp. 1934. McGraw Hill.
19. Spessard, E. A. Fertilization in a living *Oedogonium*. Bot. Gaz. **89**: 385–393. 1930.
20. Stahl, E. *Oedocladium protonema*, eine neue Oedogoniaceen-Gattung. Pring. Jahr. Wiss. Bot. (1892) **23**: 339–348. 1891.
21. Steinecke, F. Hemizellulosen bei *Oedogonium*. Bot. Archiv. **24**: 391–403. 1929.
22. Taft, C. E. The Chlorophyceae and Heterophyceae of Oklahoma. Abst. Doctors' Diss., Ohio State Univ. **16**: 213–222. 1935.
23. Tiffany, L. H. A physiological study of growth and reproduction among certain green algae. Ohio Jour. Sci. **24**: 65–100. 1924.
24. ————. The Oedogoniaceae, a Monograph. 253 pp. Author, Columbus, Ohio. 1930.
25. ————. Wille's Collection of Puerto Rican freshwater algae. Brittonia **2**: 165–176. 1936.
26. Tiffany, L. H., and Transeau, E. N. *Oedogonium* periodicity in the North Central States. Trans. Amer. Micr. Soc. **46**: 166–174. 1927.
27. Transeau, E. N. The periodicity of freshwater algae. Amer. Jour. Bot. **3**: 121–133. 1916.
28. Tuttle, A. H. Mitosis in *Oedogonium*. Jour. Exp. Zool. **9**: 143–157. 1910.
29. Wisselingh, C. van. Ueber den Ring und die Zellwand bei *Oedogonium*. Beih. Bot. Centralbl. **23**: 157–190. 1908.
30. Wurdack, Mary E. Chemical composition of the walls of certain algae. Ohio Jour. Sci. **23**: 181–191. 1923.

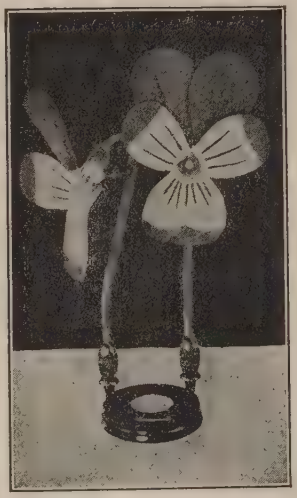
Glossary

akinetes: in the green algae, single vegetative cells developed into spore-like resting stages with much thicker walls and more abundant food reserves. See G. M. Smith: Fresh-water Algae of the U. S. They may separate from the thallus or germinate *in situ* (as in *Pithophora*).

aplanospores: non-motile spore-like cells developed from vegetative cells (singly or not) by the formation of a new wall around the protoplast distinct from the mother-cell wall; to be regarded as abortive zoospores in which the motile phase is omitted. Smith, *supra cit.* (p. 286). They may occur in both filamentous and unicellular algae, not necessarily detached, then.

blepharoplast: specialized protoplasm giving rise to the motile cilia of antherozoids.
hemicelluloses: carbohydrates which are polymers of pentose and hexose sugars; hydrolyzed by hot dilute acids and not colored blue by chlor-zinc-iodide. Anderson & Jackson.
macrophyte: any macroscopic plant.
oogamous: having sexual reproduction by unlike gametes.
oogonium: a female sexual organ, often a spherical sac, containing, in the Oedogoniales, one egg.
oospore: the immediate product of fertilization in the algae under discussion.
pH: the symbol for the logarithm of the reciprocal of hydrogen-ion activity. Values indicate degrees of alkalinity or acidity; pH 7 is neutral, higher values more alkaline, lower values more acid.
pyrenoids: minute rounded granular colorless bodies embedded in the chromatophores of green algae and associated with starch formation.

This is one of the plates in our



BOTANY MODELS CATALOG

Our enlarged and dissectible botany models are all the product of the internationally famous house.

R. BRENDEL

for whom we are exclusive dealers in U.S.A. and Canada. Our catalog No. 50 of models, specimens, preparations, gladly sent on requset. Catalog of Schmeil Botany Charts now available.

CLAY-ADAMS CO.

25 East 26th St.
New York, N. Y.

Special Lenses, Field Microscopes, Collectors' Glasses, Field Glasses, Binoculars, Microscopes, and Optical Specialties.

trades accepted

WAELDIN, INC.

117 Fulton Street New York City
Beekman 3-7337

Chronica Botanica, the year-book of plant science has been designed to bring together the research programmes of all laboratories, experimental stations, herbaria, botanic gardens, etc., to give a résumé every April of the professional and personal news of the past year and to promote co-operation between workers in the various branches of plant science in every possible way.

Chronica Botanica deals not only with general botany, taxonomy, ecology, etc., but also with agriculture, agronomy, forestry, horticulture, phytopathology, genetics, plant breeding, microbiology, soil science, agricultural bacteriology and chemistry, plant-biochemistry and pharmacognosy.

Chronica Botanica contains a complete, annotated and up-to-date list of all laboratories, expt. stations, herbaria, botanical gardens and societies connected with every branch of plant science. Special sections are devoted to the Internat. Bot. Congress and to other internat. congresses, committees and societies. It also includes an almanac of events, past, present and future, a section for correspondence, notes on new periodicals, lists of new and changed addresses and indices of names of plants, persons and societies.

Chronica Botanica *sends questionnaires every December to the Directors of all botanical laboratories, expt. stations, herbaria and gardens and to the Secretaries of all botanical societies. Answers must reach the Editor before the end of January; it is impossible to use information received after that date.*

CHRONICA BOTANICA is published every April as a single volume of about 400 pages, with numerous illustrations, bound in cloth. Annual subscription hfl. 15.-, postage extra. For prospectus, sample pages and further information, apply to the Editorial and Publishing Office, P. O. Box 8, Leiden, Holland.

This year-book is the first and only one of its kind : it contains a vast amount of hitherto unavailable information. It answers hundreds of questions which you have previously had to leave unanswered, though they were of the greatest importance for your work. An annual subscription will well repay you - you cannot afford to be without the latest issue of the "Chronica".

TRIARCH

BOTANICAL PRODUCTS

"Prepared by a Botanist for Botanists"

What the Botanical Review is accomplishing so admirably by means of the printed page, Triarch is attempting to do with laboratory materials. The fact that we sold in 1935 a greater volume than ever before indicates that we too have attained some measure of success.

For your assistance in laboratory work we now offer the following:

Over 1000 Prepared Slide Items for General Botany.

Over 300 Prepared Slide Items for Plant Pathology.

Over 100 Prepared Slide Items for Cytology.

More than 30 Commercial Wood Slides from Celloidin.

A Set of 50 Crude Drug Slides for Pharmacognosy.

More than 200 Original Photomicrographs and over 150 Original Photographs of Native Plants, Available as Prints or Lantern Slides.

Over 200 Preserved Plant Items Covering the Plant Kingdom.

Research Service in All Botanical Sciences.

A postcard will bring you any or all of our publications, and a trial order of Triarch material will be sent on approval without cost unless retained. Let us prove to you that Triarch leads!

For any of these publications write to

TRIARCH PUBLICATIONS

CATALOG NO. 3
Our standard list of prepared slides and other materials for the botanical sciences.

CATALOG NO. 3A
Our economy list of popular and routine microscope slides and prepared plants.

TRIARCH TOPICS
Our monthly news sheet, sent to all colleges and to all individuals who request it.

ACCURACY SERVICE T DEPENDABILITY

GEO. H. CONANT
RIPON, WIS.